SafePort™-Transitioning Novel Environmental Sensors from Laboratory to the Field

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SafePort™ Vision



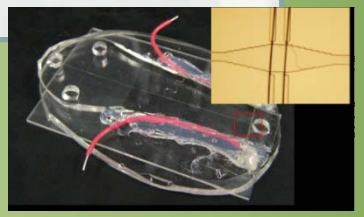

Current Approach

- > $100/sample
- Wait time measured in weeks

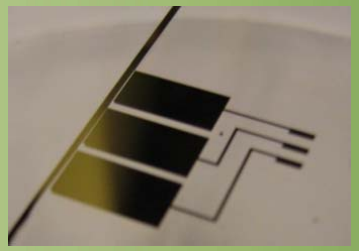
Leads to:

- Missed opportunities for prophylaxis
- Ecosystem/human health effects
- Expensive logistical and laboratory infrastructure
- Repeated sampling events

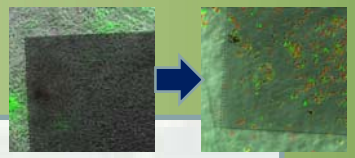
ERDC Science



Perchlorate Separation and Quantitation



Anodic Stripping Voltammetry for Pb, Cd Quantitation



Cell Based Toxicity Sensor

SafePort™ vision

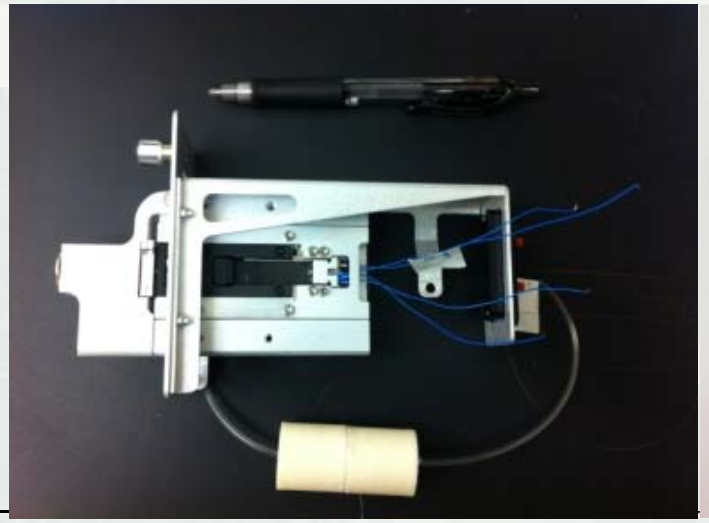
- < $10/sample
- Quantitative answers in minutes
- Minimal user technical background

Leads to:

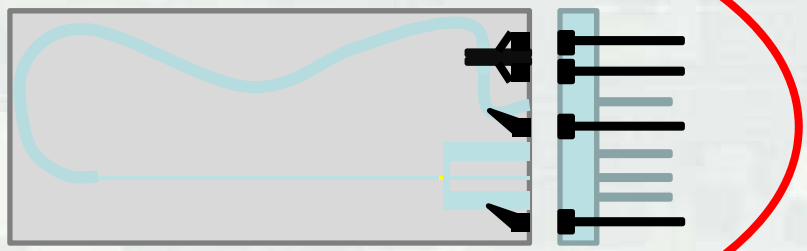
- On the spot decision making
- Reduced reliance on laboratory infrastructure
- Immediate response to contamination
- Efficient & adaptive sampling to map contaminant plume

SafePort™ Hardware Platform

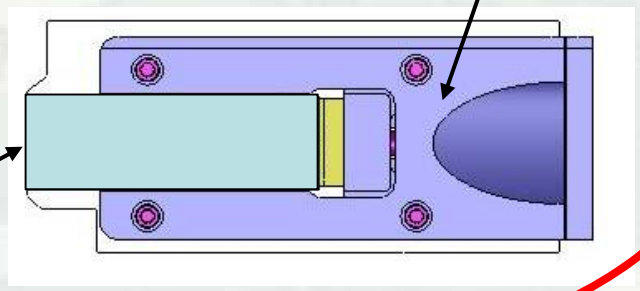
- Handheld water analysis system allows users with minimal technical background to conduct sophisticated chemical and biological analysis on site in minutes
- User selectable, insertable analysis chips can be customized for any end user application
- Robust, modular hardware incorporates fluid pumping, electrochemical and fluorescence detectors, and electronics with no moving parts

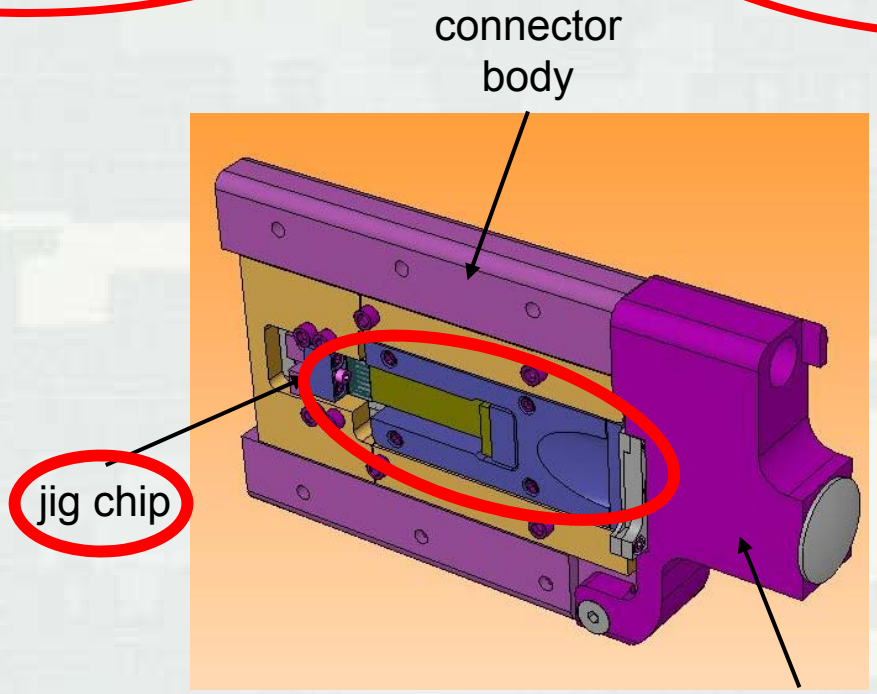


Microfluidic Hardware Design

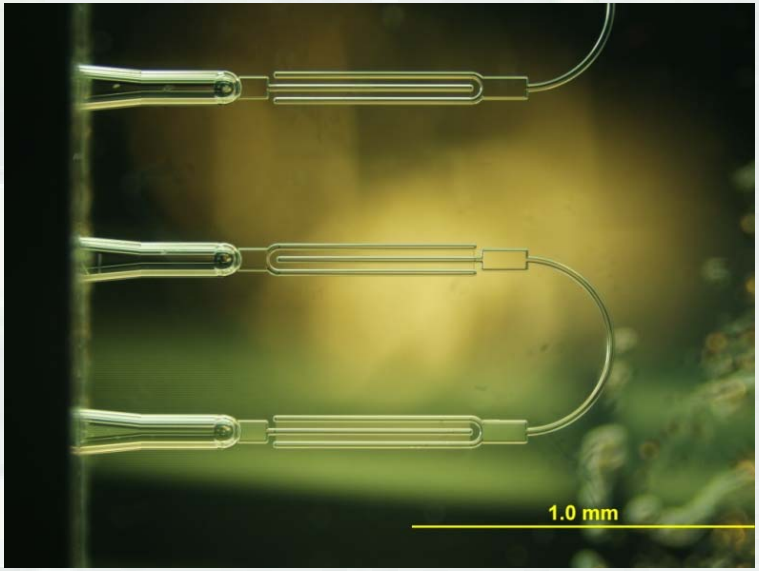


jig chip design

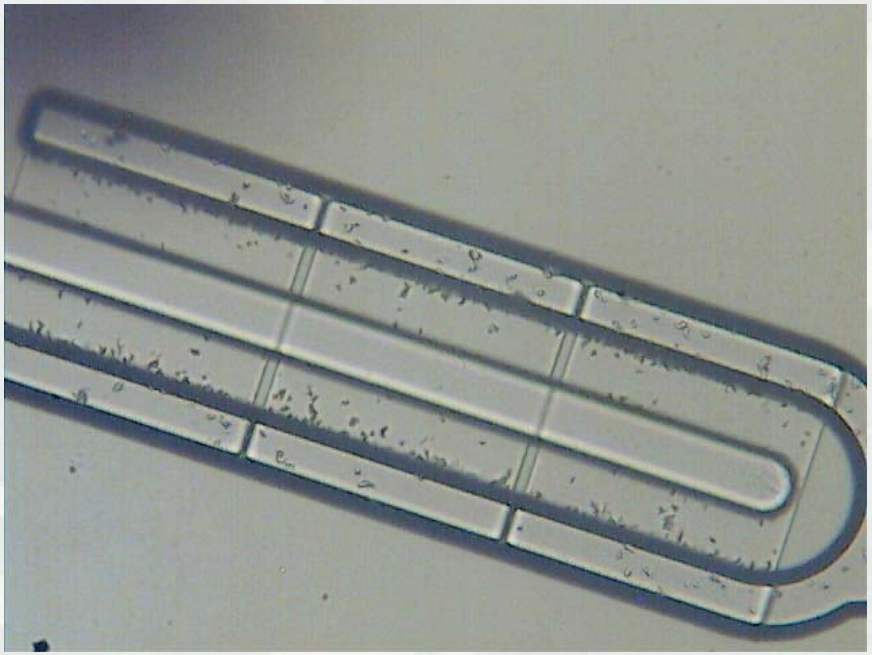




On-board Filtration



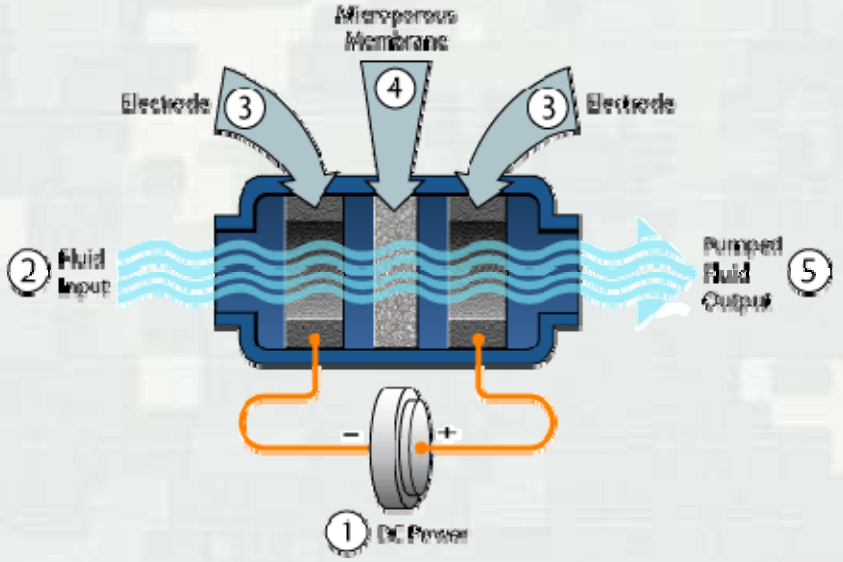
On-chip filtration allows injection of ‘dirty’ real world samples

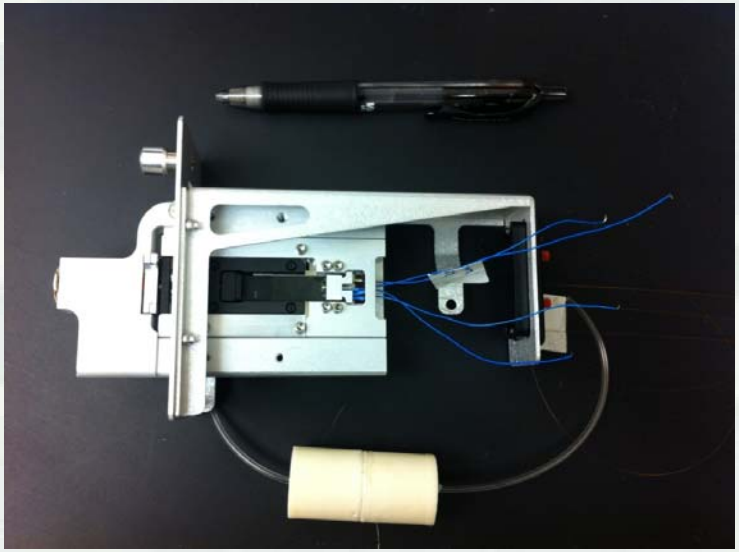


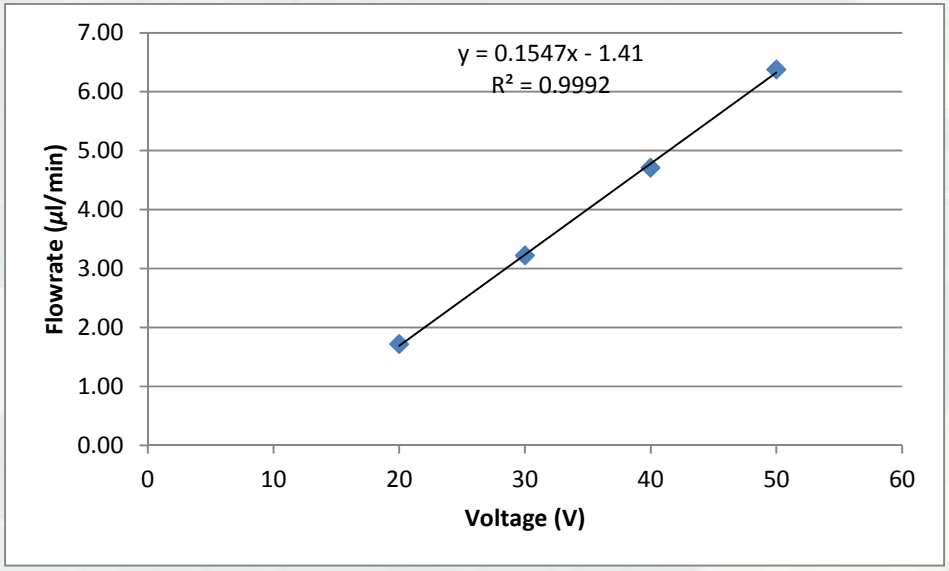
Filter: 70 runs, pressure 250 psi

Electrokinetic Pumps

- Transports fluid through the SafePort™ chassis/chips
- No moving parts = very robust
- Very low power →
  5 mW at maximum flow rate

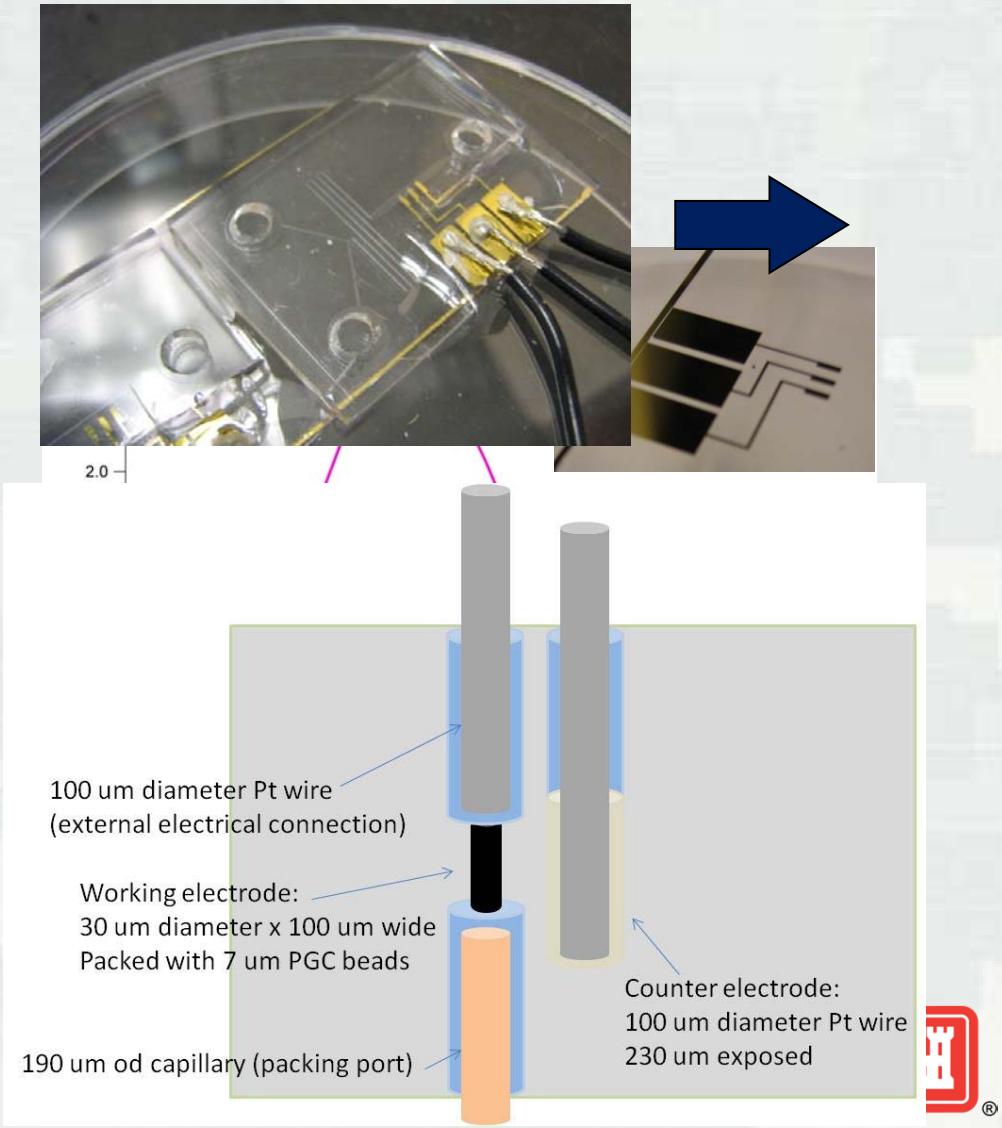




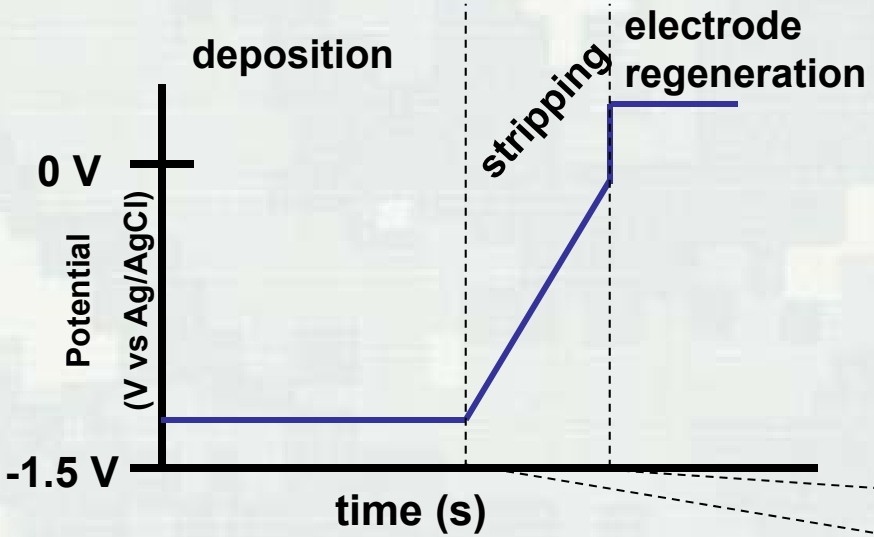


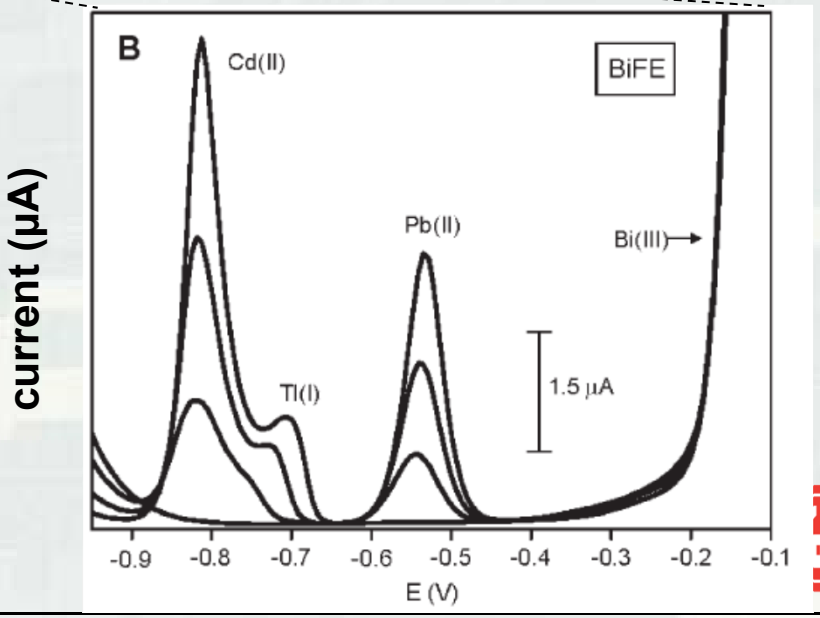
Heavy Metal Quantitation Chip

- Simultaneous detection of multiple analytes
  - Pb, Cd, Cu, Tl, etc.
- Low ppb detection limits
- Anodic stripping voltammetry (ASV) is a portable, low cost solution compared to typical methods (atomic absorption or mass spec.) which are costly and require large lab-based instrumentation
- Expandable - capability to analyze additional species by simply changing the reagent mixture and/or electrode configuration

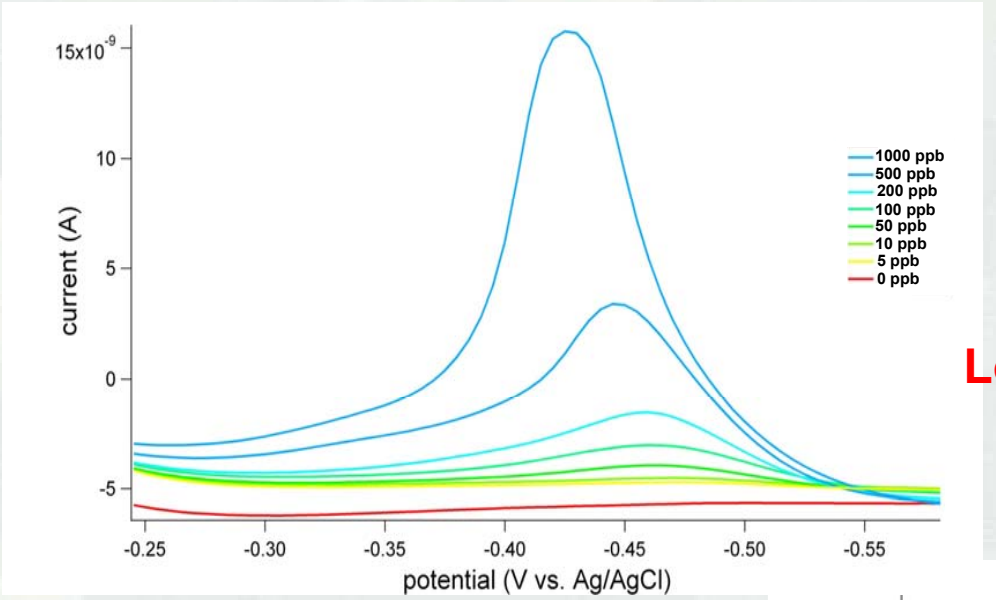


Anodic Stripping Voltammetry Analysis

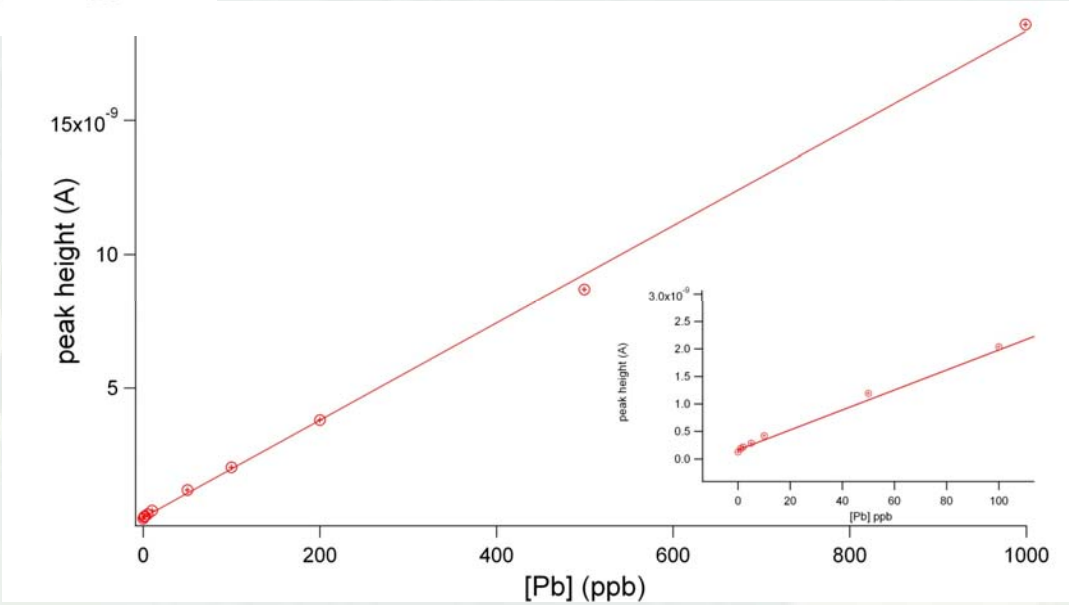




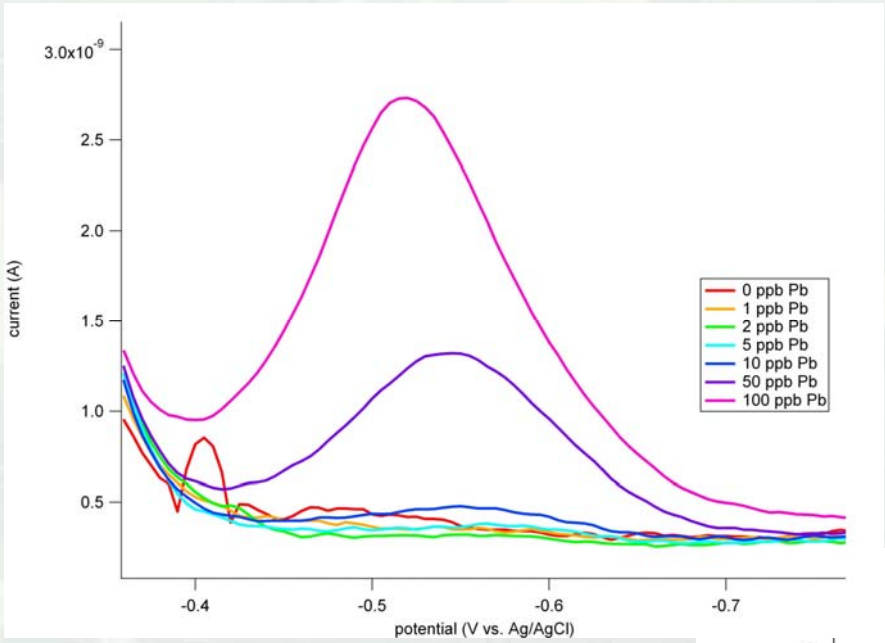
Pb Contaminant Analysis



LoD = 5 ppb

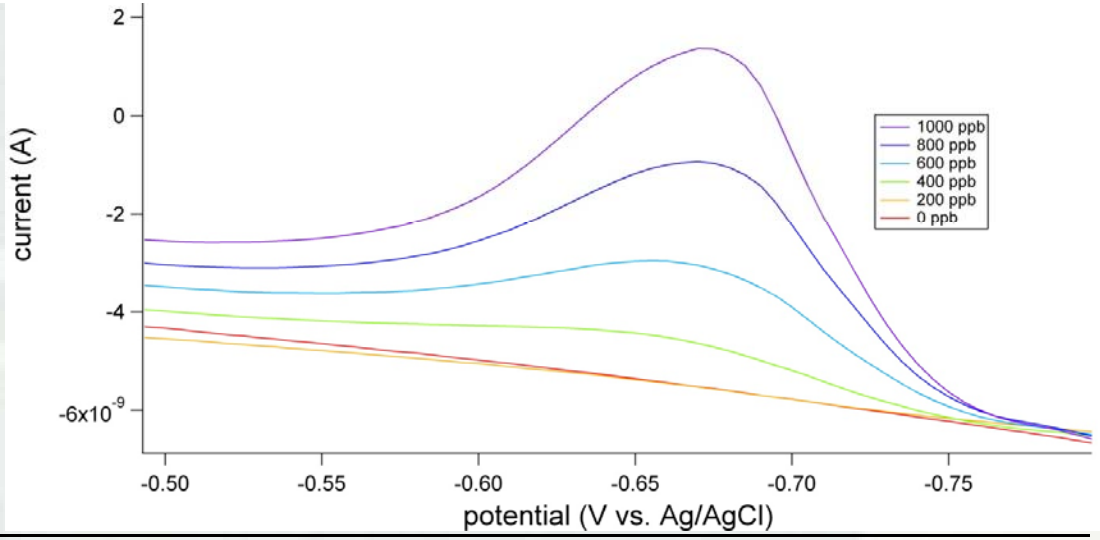


Pb and Cd Contaminant Analysis

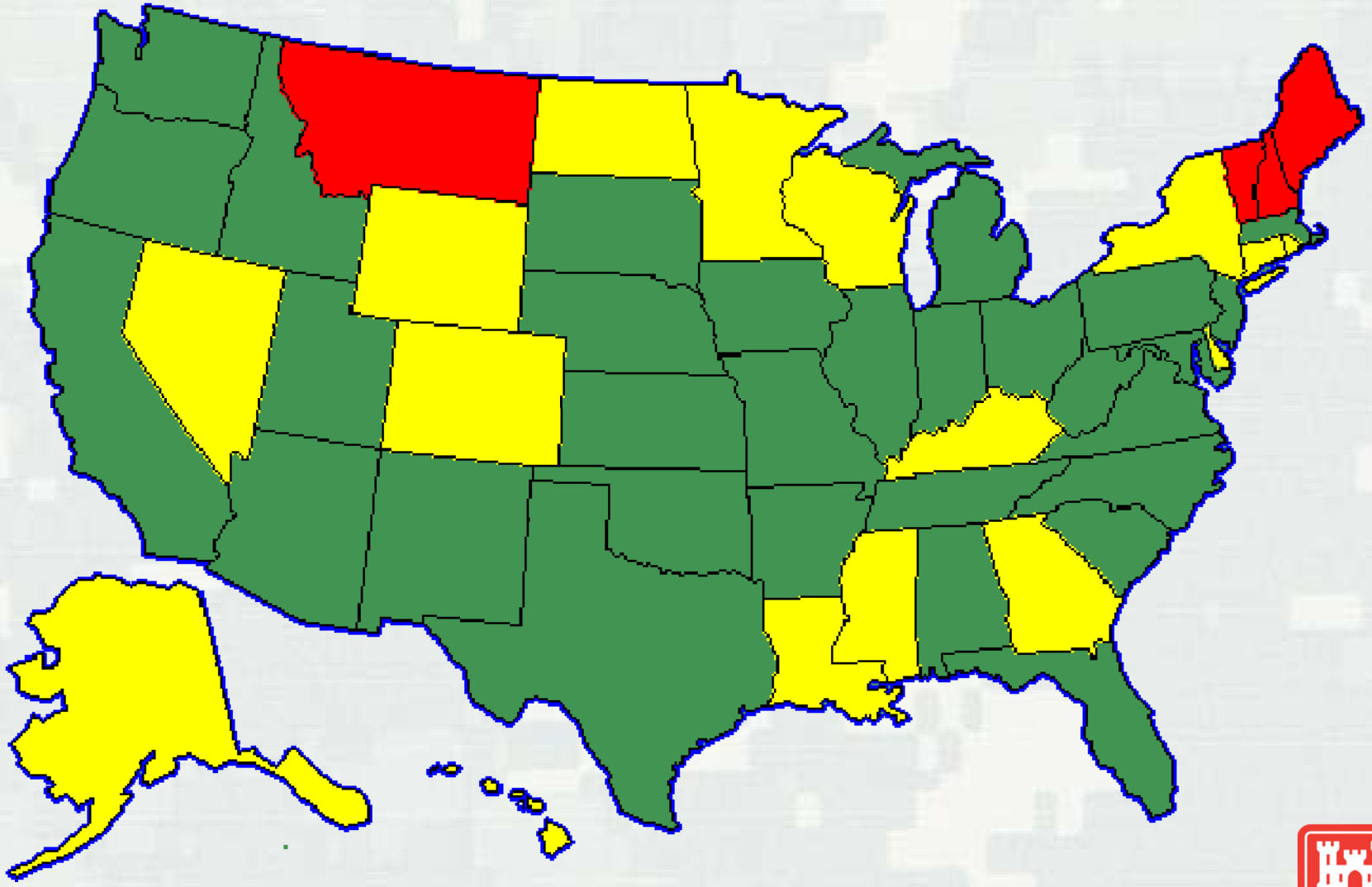


Pb-spiked tap water

Cadmium ASV results



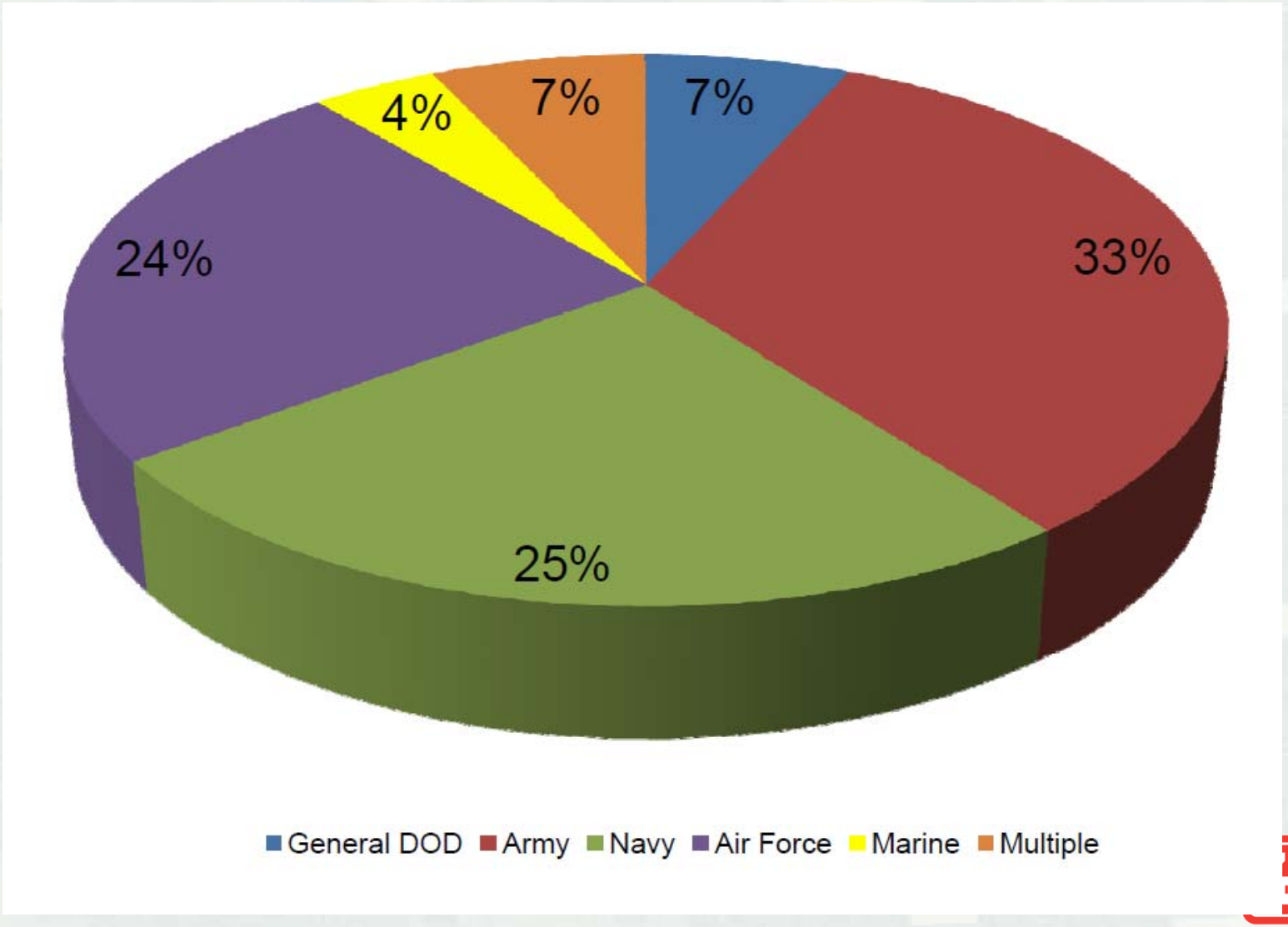
Perchlorate Detected within the DOD



Data collected by the Chemical and Material Risk Management Directorate
http://www.denix.osd.mil/cmrmd/ECMR/Perchlorate/StateSummary.cfm

BUILDING STRONG®

Perchlorate Detected by DoD Branch



Data collected by the Chemical and Material Risk Management Directorate
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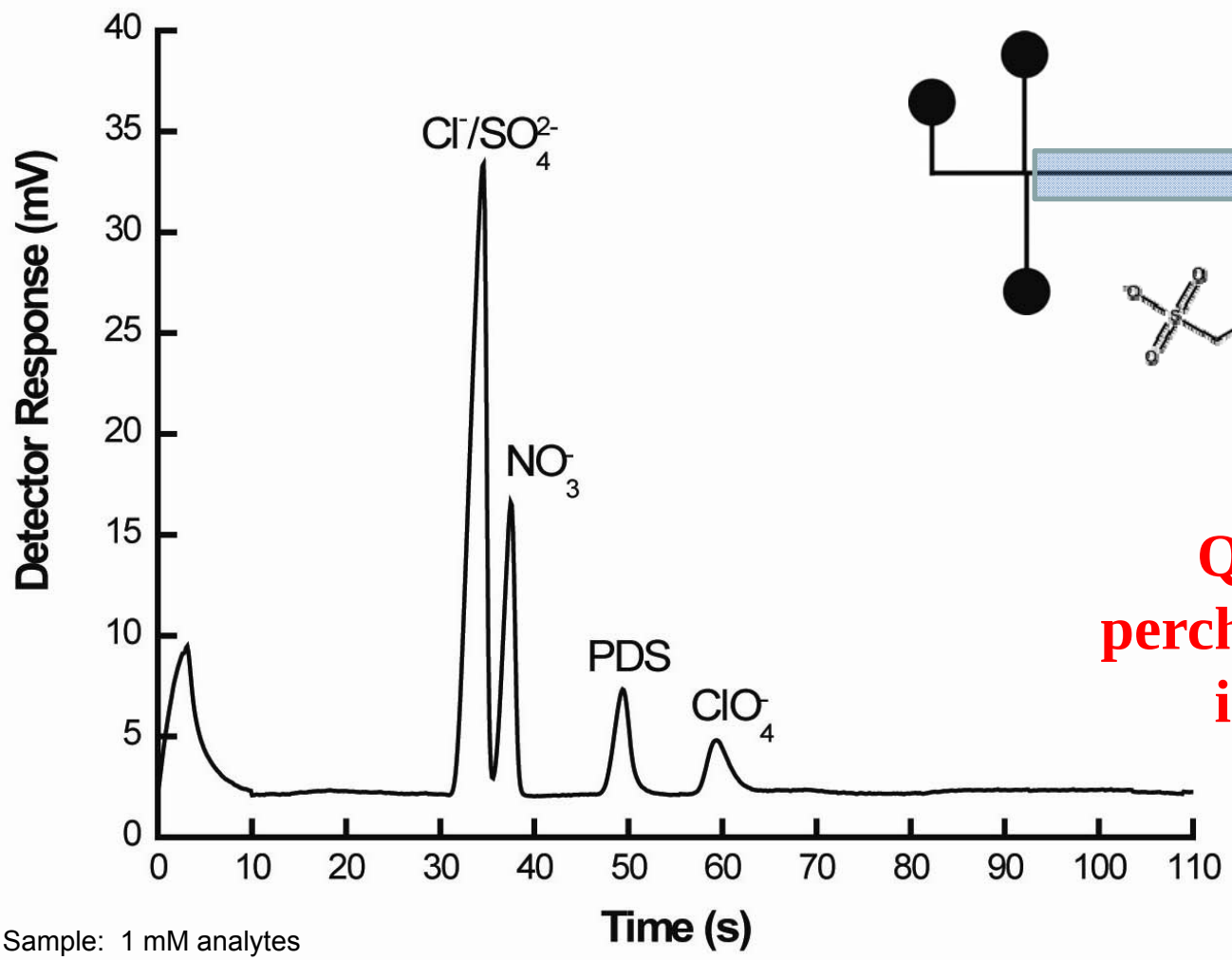
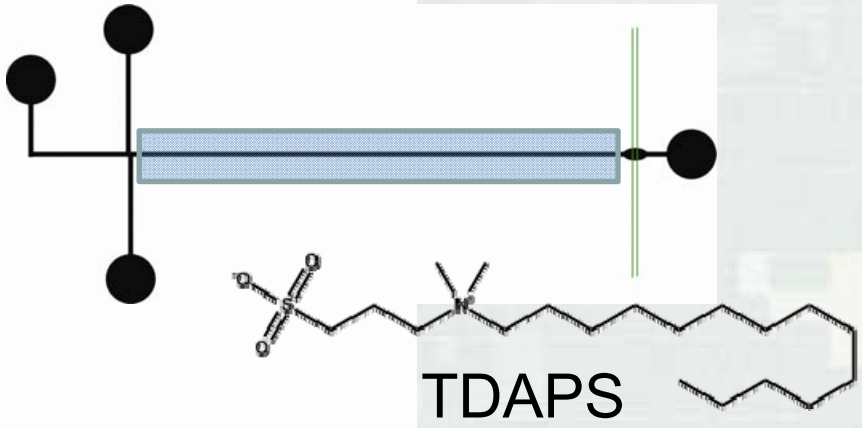
Microchip Capillary Electrophoresis

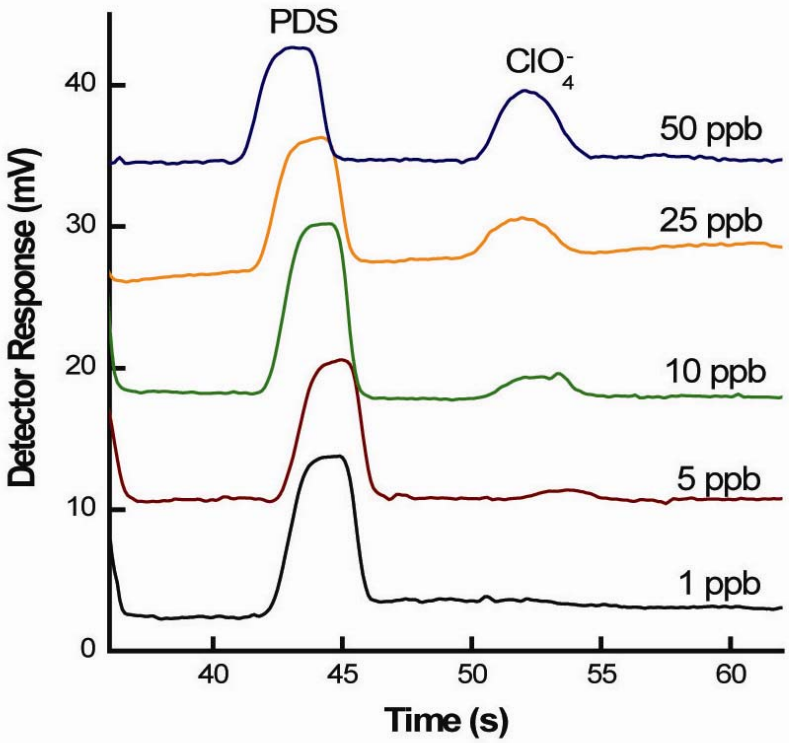


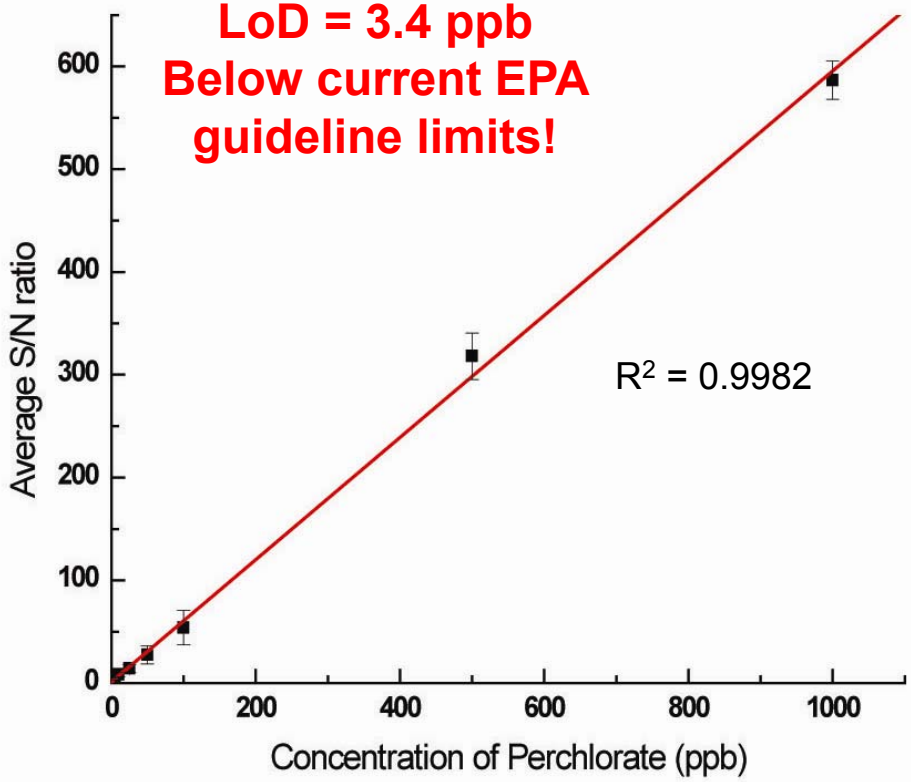


Quantitative perchlorate analysis in only 70 s

Sample: 1 mM analytes
Conditions: -350 V·cm^{-1}, 3 s injection,
Electrolyte (BGE): 10 mM nicotinic acid, 1.0 mM TDAPS, pH 3.6.
Detector range = 100 µS

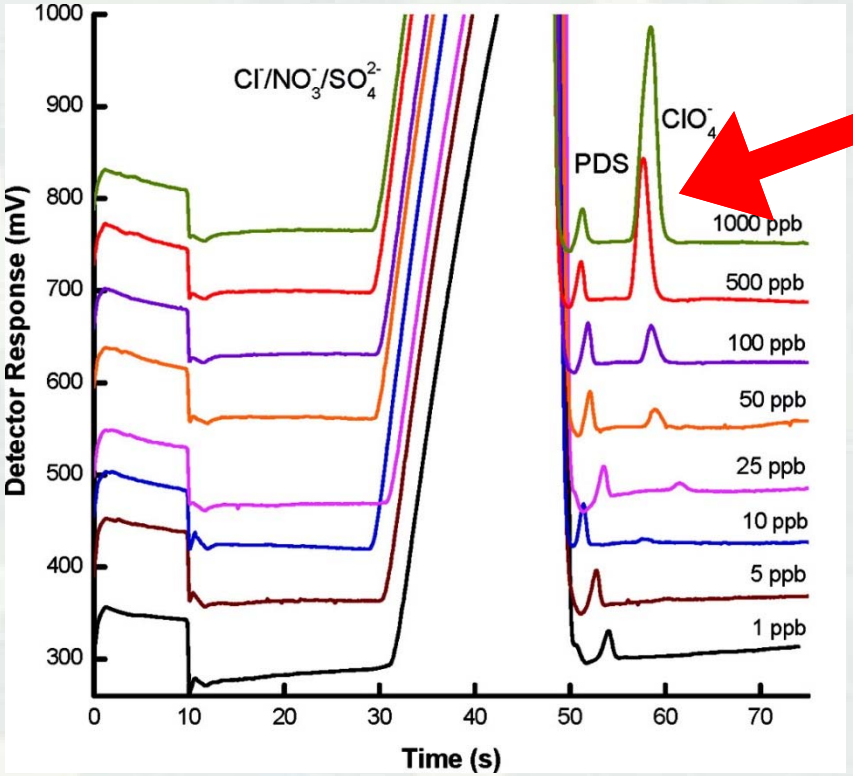
Calibration Curve/Detection Limit



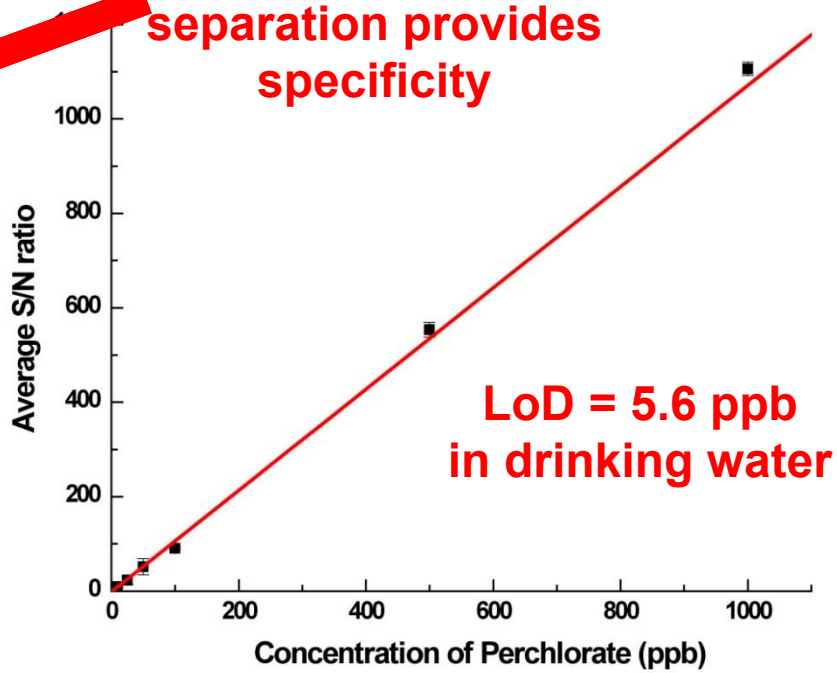


- Sample: 0.12 ppm PDS, 1-50 ppb perchlorate in 10% BGE
- Conditions: -350 V·cm^{-1}, 3.0 s injections
- BGE: 10 mM nicotinic acid, 1.0 mM TDAPS, pH 3.6.
- Detector range = 100 µS.

Spiked Drinking Water Analysis



Chromatographic separation provides specificity



LoD = 5.6 ppb in drinking water

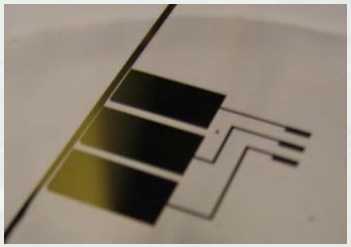
Samples: Drinking water spiked with 0.12 ppm PDS and 1-1000 ppb perchlorate.
Conditions: -350 V·cm^{-1}, 10 s injection
BGE: 10 mM nicotinic acid, 1.0 mM TDAPS, pH 3.6.
Detector range = 50 µS.

Detection Limit (Other Studies)

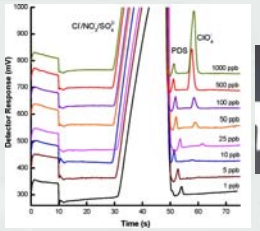
2D Ion chromatography Conductivity Detection	0.05 ppb	Journal of Chromatography A 1155 (1), pp. 15-21
Ion chromatography Mass Spectrometric Detection	0.02-0.05 ppb	Journal of Chromatography A 1133 (1-2), pp. 215-220

Current and Upcoming Capabilities

- Heavy metal quantitation (Entering DemVal)
  - Current chip quantifies lead and cadmium with ppb sensitivity in minutes
  - Readily modified to quantify other metals (*e.g.* U, Cr, others)
  - Capability to modify for nearly any electrochemical assay



- Perchlorate (ClO_4) quantitation (Entering DemVal)
  - Currently quantifies perchlorate in ground water at ppb levels in minutes
  - Chip chemistry under modification to separate and detect water-borne cationic and anionic indicators of homemade/improvised explosive (HME/IED) manufacture
  - Capability to separate, detect, and quantify virtually any cation or anion



- DNA/RNA detection platform (6.3 Development)
  - Rapid extraction and detection of nucleic acids (DNA or RNA) from cells and spores in water samples
  - Can be tailored to specific biothreat agents & strains, invasive species, pathogens, etc.
  - RNA detection capability allows assessment of organism viability for applications such as water treatment or decontamination efficacy

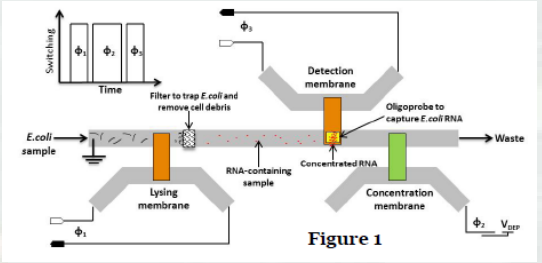
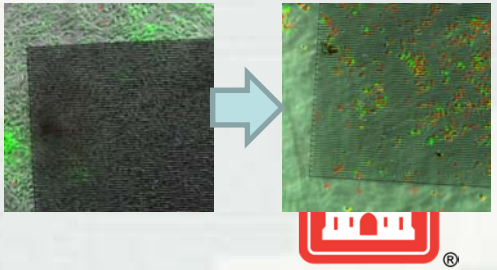
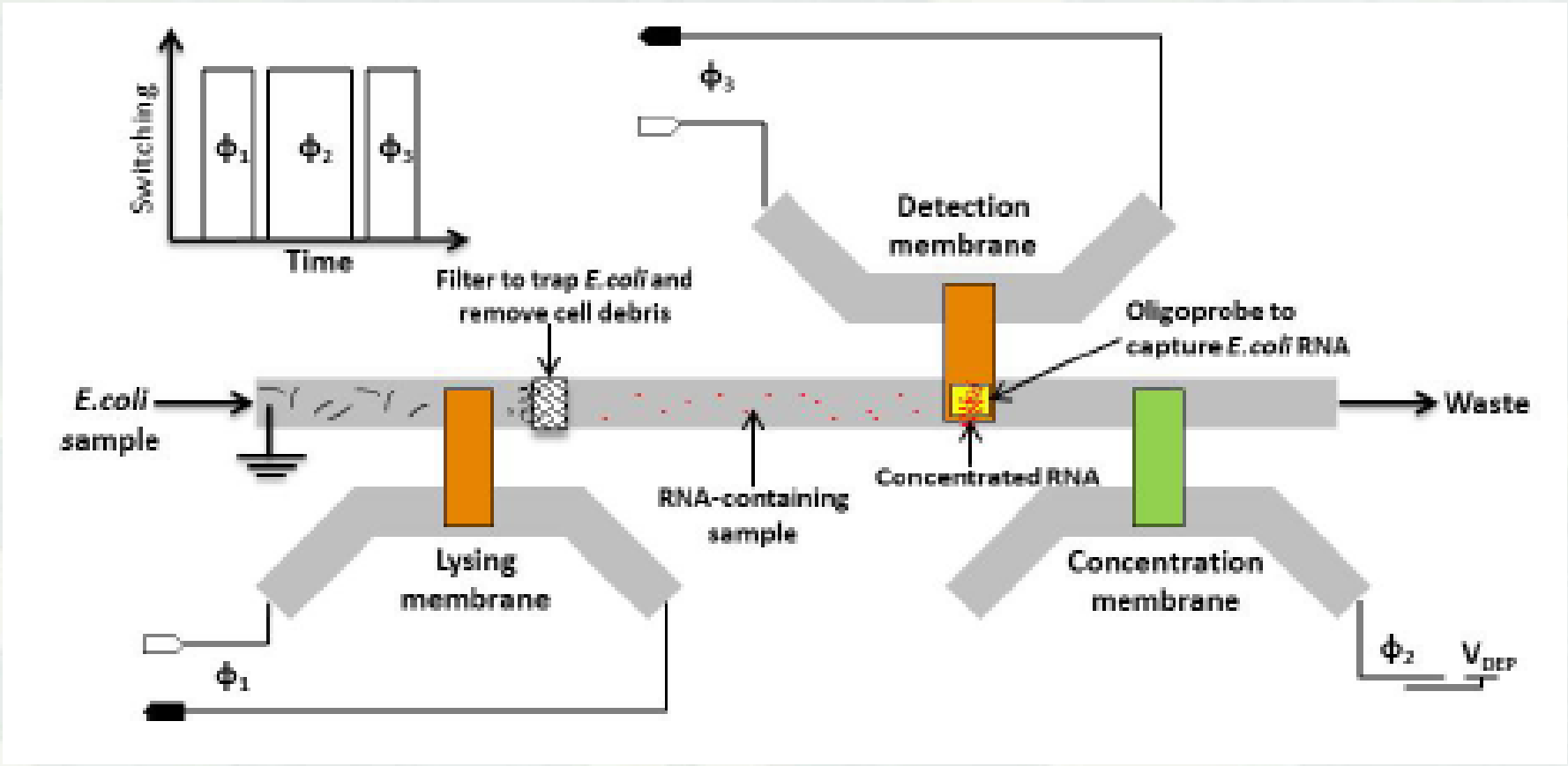


Figure 1

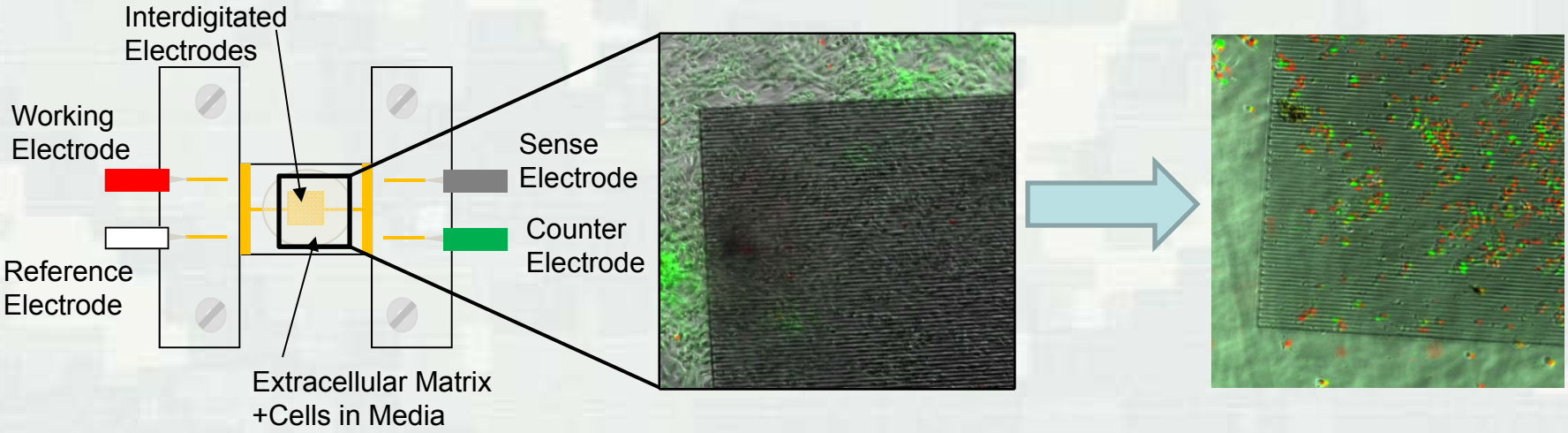
- Broad-spectrum biologically-based assays (6.2)
  - Detection of emerging/unidentified compounds due to toxic response
  - Universal toxicity biosensor for rapid screening of water resources
  - Physiologically-based detection of known and unknown threat agents
  - Uses biological organisms, extracted organelles, or synthetic mimics as sensing elements

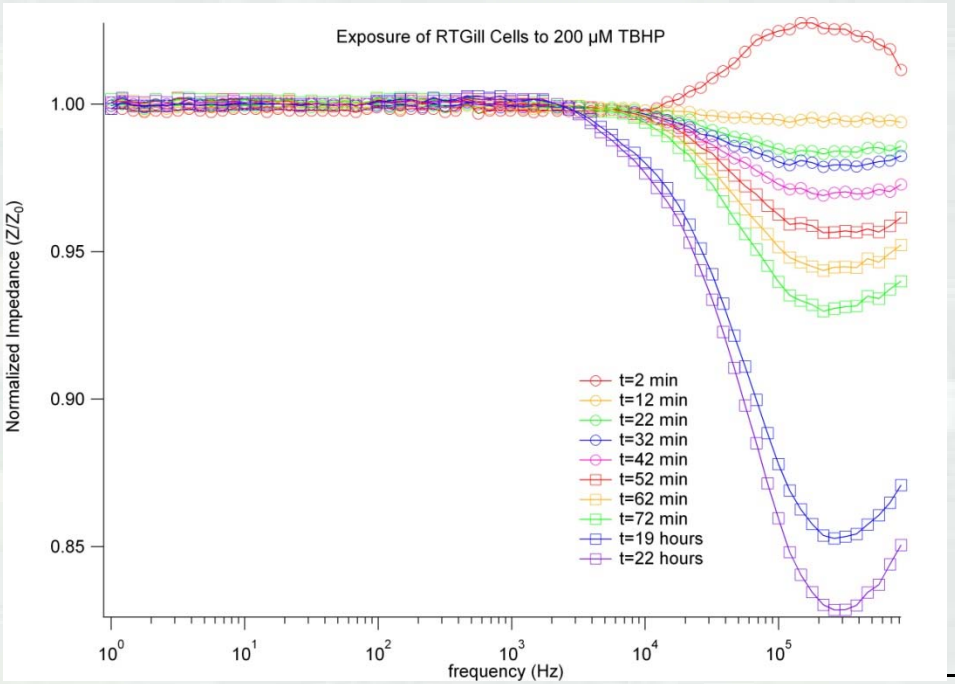


DNA/RNA Detection Platform



Cell-based Water Toxicity Screening





- Electronic sensing of cell stress and death
- Fourier transform-based impedance technique reduces measurement-induced cell perturbation and increases measurement speed from 10s of seconds to milliseconds
- Cells seeded on extracellular matrix coated interdigitated electrodes
- Temporal evolution of impedance is correlated to the extent of toxicant-induced cellular changes

Summary

- The SafePort™ hardware platform with heavy metal and perchlorate quantitative analysis modules will be ready for field demonstration and validation in 2nd quarter FY13.
- Microfluidic chips are reusable for up to 100 analyses before they must be discarded. Each chip will cost ~ $500, while the hardware chassis will cost $16K

  (~$10 per analysis versus $100+ currently).
- DNA/RNA detection modules will be ready for demonstration and validation early FY14, while biologically based assays will be ready mid-FY14.

  Additional analyses and chip modules for SafePort™ chassis can be developed as requested.

Acknowledgments

Dr. Don M. Cropek
Dr. Travis L. King

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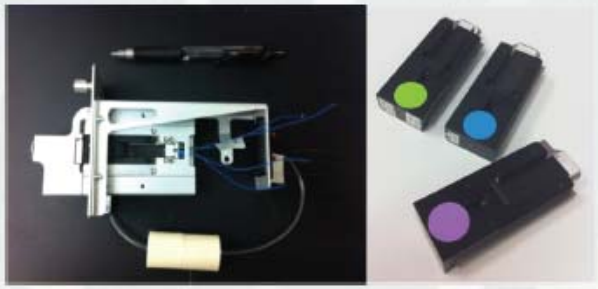
SafePort™



What is SafePort™?

SafePort™ is a portable water analysis system that harnesses technological advances in microfluidic chip design and fabrication to bring rapid chemical analysis to the field-minimizing down time while awaiting results and substantially reducing analytical costs. The goal of SafePort™ is to bring microfluidics-based analysis of water samples to the field with 'push button' operating simplicity, providing accurate, actionable answers to military personnel in minutes.

What does SafePort™ consist of?

The system consists of a portable, user-friendly hardware unit that accepts various user-selectable, interchangeable microfluidic chips for rapid detection and quantitation of chemical species in water and for toxicity screening. The hardware platform with heavy metal and perchlorate quantitative analysis modules will be ready for field demonstration and validation in 2nd quarter FY13. The chips are reusable for up to 100 analyses before they must be discarded. DNA/RNA detection modules will be ready for demonstration and validation early FY14, while biologically based assays will be ready mid-FY14. *Additional analyses and chip modules for SafePort™ chassis can be developed as requested.*

How much does SafePort™ cost?

Each chip will cost ~ $500, while the hardware chassis will cost $16K. (~$10 per analysis versus $100+ currently)

SafePort™ Real-Time Analysis versus Current Testing Protocols

SafePort™

- < $10/sample
- Quantitative answers in minutes
  - Lead (Pb) LOD 5 ppb in 5 min
  - Perchlorate LOD 5 ppb in 70s
- Minimal user technical background

  Leads to:
  - -On the spot decision making
  - -Reduced reliance on laboratory infrastructure
  - -Immediate response to contamination
  - -Efficient and adaptive sampling to map contaminant plume

Current Approach

- > $100/sample
- Wait time measured in weeks

  Leads to:
  - -Missed opportunities for prophylaxis
  - -Ecosystem/human health effects
  - -Expensive logistical and laboratory infrastructure
  - -Repeated sampling events

For more information, please contact:

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